

An Empirical Model for the Solar Wind Velocity

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An analytic expression for the average radial component of the Solar Wind velocity between 1 solar radius and 1 AU is developed as follows:

$$v_r(r) = \left[\frac{440}{r^{-0.3} + 3.35 \times 10^{-7} r^{-4.0}} \right] \text{ km/second}$$

where r is the radial distance in AU. The model is constructed by (1) Assuming the conservation of particle flow in the Solar Wind and (2) Application of a twelve-year average measured value of the Solar Wind radial velocity at 1 AU.

I. Introduction

Starting with the work of Parker in the late 1950s, many coronal investigators have attempted to formulate a model of the Solar Wind. These attempts usually take the form of making certain assumptions which define the applicable equations, and then solving these equations in the region between 1 solar radius and 1 AU. In the final step, boundary values at 1 solar radius based on observations or assumptions are incorporated, and the model predicted values of the observables (density, Solar Wind velocity, proton temperature, electron temperature) at 1 AU are compared to the corresponding in situ measurements. To date, none of the theoretical attempts have been able to correctly predict the in situ measured average values of all four observables. Of the four parameters, only electron density has been experimentally determined (by a variety of methods) over the full range of radial distances from 1 solar radius to 1 AU. Considering that particle flow is conserved in the Solar Wind (Ref. 1),

$$N_e(r)v_r(r)r^2 = K$$

where

$N_e(r)$ = Electron density

$v_r(r)$ = Radial component of the Solar Wind velocity

r = Radial distance

one can immediately write the radially dependent expression for $v_r(r)$ in terms of $N_e(r)$. Although this empirical process adds nothing to the theoretical understanding of the Solar Wind, it is here considered that the generation of such an analytical expression for the radial component of the Solar Wind velocity would:

- (1) Produce the most accurate model in the sense of being the most closely tied to actual observations (of electron density).
- (2) Produce a very convenient model for use in modelling other coronal parameters, such as spectral broadening.

II. The Model

To begin, one requires an electron density model. For this purpose, the electron density model determined from S-band Viking doppler phase fluctuations (Ref. 2) will be adopted:

$$N_e(r) = \frac{2.39 \times 10^8}{r^6} + \frac{1.67 \times 10^6}{r^{2.30}}$$

where $N_e(r)$ is the electron density in electrons/cm³ and r is the radial distance in solar radii. This model yields the following values:

<u>r, solar radii</u>	<u>$N_e(r)$, electrons/cm³</u>
1	2.41×10^8
10	8610
215	7.2

At $r = 1$ the model is in good agreement with eclipse observations (Table I, Ref. 1), at $r = 10$ the model is in good agreement with eclipse observations and pulsar time delay measurements (Ref. 3), and at 1 AU the model is in good agreement with in situ density measurements (Ref. 4).

Next, one requires a boundary value for the Solar Wind radial velocity; the obvious choice is the average measured value of $v_r(r)$ at 1 AU. Gosling (Ref. 5) has recently reported average Solar Wind velocities for the period 1962–1974; the average value for the entire 12-year period is:

$$v_r(r = 215) = 440 \text{ km/second}$$

The above value will be adopted here.

Combining the electron density function with the boundary value of the radial Solar Wind velocity at 1 AU, one arrives at:

$$v_r(r) = \left[\frac{440}{r^{-0.3} + 3.35 \times 10^{-7} r^{-4.0}} \right] \text{ km/second}$$

where r is the radial distance in AU. This model for the radial Solar Wind velocity is applicable over the region 1 solar radius to 1 AU and yields:

<u>r, AU</u>	<u>$v_r(r)$, km/second</u>
(1/215)	0.61
(10/215)	170
(215/215)	440

It is of interest to briefly compare these values to theoretical results. Four models in Ref. 6 at 1 solar radius yield an average value of:

$$v_r(1/215) = 2.9 \text{ km/second}$$

with values ranging from 0.3 to 5.8 km/second. Three models mentioned in Ref. 3, produce an average value at 10 solar radii of:

$$v_r(10/215) = 172 \text{ km/second}$$

with individual values ranging from 160 to 185 km/second. Figure 1 compares the empirical velocity model to a theoretical model of Brandt, Wolff and Cassinelli (Ref. 7), while Fig. 2 makes a similar comparison to the “two fluid” models of Hartles and Barnes and Wolff, Brandt, and Southwick.

References

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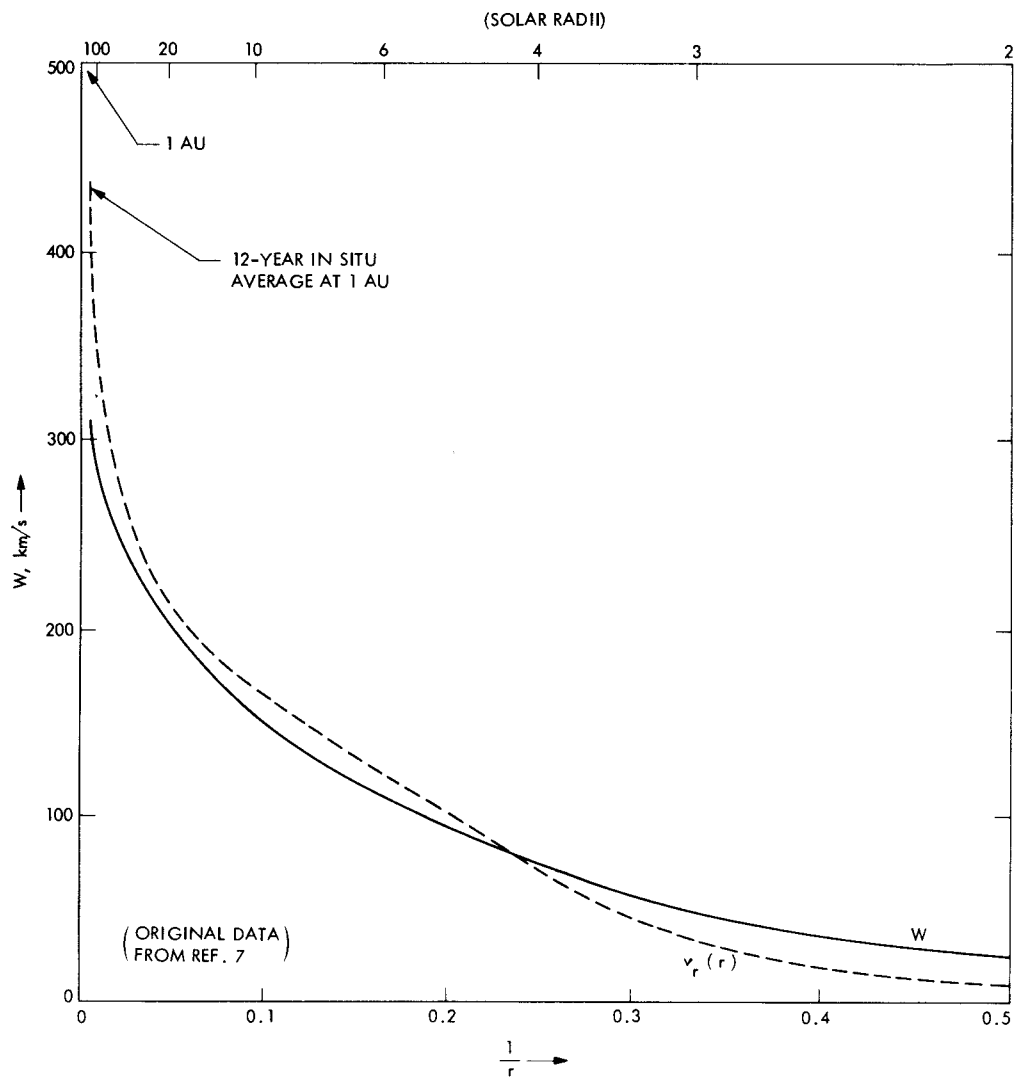


Fig. 1. Empirical Solar Wind velocity model ($v_r(r)$) compared to theoretical model of Brandt, Wolff, and Cassinelli (W)

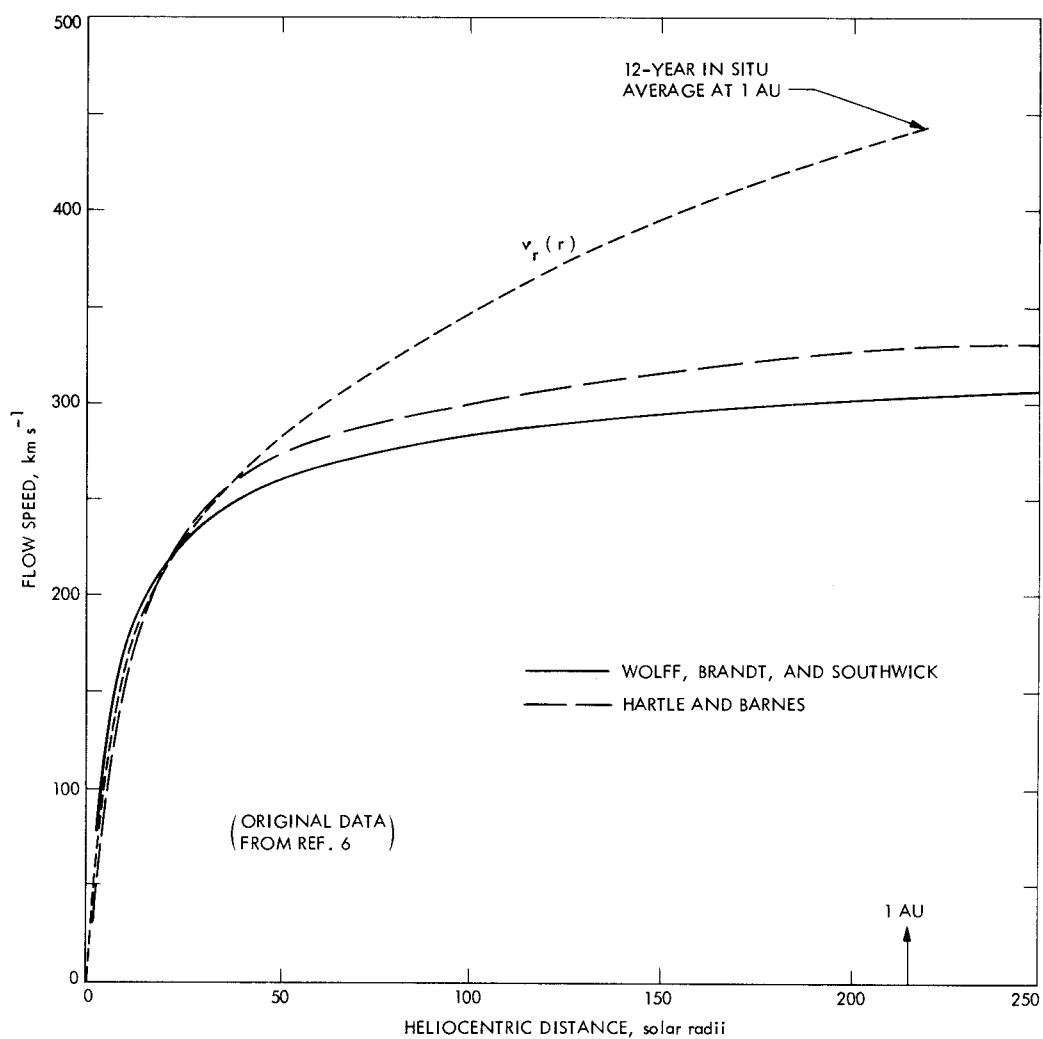


Fig. 2. Empirical Solar Wind velocity model ($v_r(r)$) compared to the two fluid models of Hartle and Barnes and Wolff, Brandt, and Southwick